

Invited article

The use of forensic radiology in determination of unexplained head injuries in child mummies – Cause of death or mummification damage?

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ABSTRACT

The role of forensic radiology imaging in the study of two ancient Egyptian wrapped child mummies allowed for different views of areas of interest where there was uncertainty in the interpretation of head injuries that may have been related to cause of death or mummification damage. The objective of this study was to determine the cause of the head injuries. Images were obtained with a Toshiba Aquilion 64 Computerised Tomography (CT) scanner set to acquire $64 \times 0.5 \text{ mm}^2$ data that was loaded into a Vitrea 2 advanced visualisation workstation for processing. Ancient texts and recent publications were consulted for descriptions of mummification techniques. Virtual images showed that both children had suffered comminuted fractures of the skull. One child had been eviscerated and appeared to have been excerebrated via the anterior fontanelle during mummification. The second child also suffered a comminuted fracture which was at the vertex of the skull but had not been excerebrated or eviscerated. The injury to the skull of this child suggested that the defect was caused by a sharp edged tool and that this injury may have caused death.

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1. Introduction

The identification of cause of death in ancient Egyptian child mummies has proved difficult due to the post mortem damage that often occurred during the invasive mummification practices. Care was also required in the interpretation of the injuries seen in radiographic images of the deceased. Early x-ray images gave basic information about the bodies and CT scans added to this information but now images constructed by advanced visual workstations have produced detailed virtual data that has allowed for more accurate reporting on injuries and cause of death [1,2].

Virtual images from Computerised Tomography (CT) data have revolutionised the study of ancient mummified remains and removed the need for destructive procedures linked to unwrapping of bodies [3,4]. This technology has been used in a number of forensic pathology institutions including the Victorian Institute of Forensic Medicine (VIFM) Australia [5,6]. In modern forensic practice the virtual images, as an adjunct to autopsy, have given more detailed information about the state of bodies including age, cause of death, injuries, inclusions and in some cases has removed the necessity for invasive examination required in traditional autopsy practices [7–9].

In mummy research the use of the virtual data has expanded

the range of images available of possible peri-mortem or post-mortem injuries and afforded more information about ancient Egyptian mummification practices that were not previously reported [10,11]. CT scanning employed non-invasive and non-destructive methodology for the collection of the maximum amount of data about areas of interest with the body [12,13]. In addition the input of raw CT scan data into advanced visualisation workstations provided virtual information about age, sex, injuries and cause of death that was previously difficult to obtain [14,15]. High resolution multi-planar reconstructions (MPR), 3D reconstructions, surface rendered images and virtual reality images of areas of interest on the external aspects and within Preserved bodies now showed specific parts of the body [16].

Forensic radiology protocols were utilized in the study of two small child mummies from the human remains collection of the British Museum; who had been mummified and wrapped approximately two thousand years ago [17]. The mummified bodies presented unique problems in the interpretation of the radiological data due to external linen wrappings, desiccation of the tissue and damage caused by embalmers during the mummification process. The children lived and died in the Graeco/Roman Period (332 BCE – c 395 CE); when the Greeks and later the Romans ruled Egypt [18–20].

Very little is known about children from of ancient Egypt except for some modern studies which have investigated their remains for clues about how they lived and died [21,22]. The children lived in towns and cities along the Nile Valley and in oases where there were risks of early death [23]. Environmental hazards in the form of the Nile River and other water sources presented dangers or even attack by river animals. Severe injuries and fractures caused by accidents within the home or abuse by family members were all also risks for these children [24–26]. The ancient Egyptians attempted to protect their children from accident, injury or even malevolent forces although from a young age children were expected to assist the family inside and outside the home [27]. The life expectancy of a child depended on many factors and even with the attention of ancient medical practitioners the likelihood of attaining adulthood was sometimes remote [28–30].

When death occurred the child was mummified if the family had sufficient resources for preservation of the body [31]. Mummification procedures were invasive and caused injuries to the body when excerebration and evisceration were performed [32]. These practices were executed with varying degrees of competence depending on the skill or supervision of the embalmer but there was an expectation that minimal damage would occur during the procedure [33].

There were two main ancient sources which described mummification practices and these were written by Greek historians Herodotus and Diodorus Siculus. Herodotus wrote of three methods including the most expensive which included evisceration via the left flank, excerebration using a hook inserted into the cranial cavity via the nose and desiccation of the body in natron. Natron was a naturally occurring salt composed of varying ratios of sodium chloride, sodium sulphate, sodium carbonate and sodium bi-carbonate from the Wadi Natrun in Egypt [34]. Diodorus Siculus recorded Graeco/Roman practices when more bodies were mummified and added information concerning the retention of the kidneys and the heart [35,12].

The purpose of this research was to determine the cause of the unusual and unexplained head injuries that were detected during the CT scanning of the mummified bodies of two ancient Egyptian children. In particular the research investigated whether the injuries observed were the cause of death or were related an invasive nature of a mummification procedure.

2. Materials and methods

Two British Museum child mummies were selected for CT scanning after a study of x-ray films and reports from a radiological investigation in 1968. A macroscopic investigation of the wrapped bodies was carried out at the museum to determine suitability for CT scanning. The texts of Herodotus and Diodorus Siculus were consulted for guidelines to mummification practices and likely variations that may have been present in the mummies. The mummies were numbered 1 and 2 for the purpose of identification in this research. The British Museum acquisition number for mummy 1 was EA 6723 and for mummy 2 it was EA 54053.

The mummies were CT-scanned at the Blackheath Hospital (BMI Healthcare) London, UK, on a Toshiba Aquilion 64 (Toshiba Medical Systems Corporation, Tochigi, Japan) CT system, using a spiral acquisition method with a collimation of $64 \times 0.5 \text{ mm}^2$. The images were then reconstructed into a thin slice isotropic volume data set for optimal high resolution, allowing additional 3D multi-planar reconstructions (MPR) to be performed with varying fields of view. The workstation also allowed for a Maximum Intensity Projection (MIP) mode to identify densities and to virtually remove bandages. This permitted more detailed information to be

available about specific areas of interest of the skull and within the cranial cavity when the CT scan data was loaded into a Vitrea 2 (Vital Images, Minnetonka, MN, USA) advanced visualisation workstation for further processing in London and at the VIFM, Melbourne, Australia.

A modern dental development chart was consulted to estimate the approximate age at death of both children [36]. The sex of each of these children was determined by identification of the genitalia in the 3D reconstructions from the CT scan data.

3. Results

Mummy 1 was the body of a male child and mummy 2 was that of a female child who were both of unknown provenance and had been described as from the Roman Period in the records of the British Museum. The bodies were wrapped in linen bandages of varying thickness and quality. The extensive bandages were devoid of any external decoration such as masks, chest or foot plates. The bandages of both mummies were held in place by diagonal and horizontal linen strips which had been placed at various intervals on the wrapped bodies.

An examination of the 3D multi-planar (MPR) reconstructions showed that the deciduous dental development indicated that both the children were approximately 1.5–2.5 years at death. Additional images showed that the cervical vertebrae of each child were in good condition with the heads flexed forward towards the sternum; with chins on the chests. Mummy 1 showed evidence of a fractured thoracic spine at the level of T8-9 with displacement of the distal portion to the right. The spine of mummy 2 was in normal alignment and without damage. The nose of mummy 1 was not compressed but in mummy 2 the nose had been compressed. Both nasal septa were intact and there was no evidence that the cribriform plate of the ethmoid bone had been breached in either mummy.

Mummy 1 had been eviscerated via an incision in the left flank and a large quantity of fabric had been inserted into the body through this defect. A number of small unidentified objects were discovered within the thorax and abdomen of mummy 1. In mummy 2 the internal organs were in situ and there was no evidence of evisceration.

A comminuted fracture was observed in the skull of mummy 1 in the area of the anterior fontanelle extending into the left parietal bone. The corresponding defect was irregular and measured approximately $32 \text{ mm} \times 24 \text{ mm}$ (Fig. 1).

Five fragments of skull of various sizes were identified in the

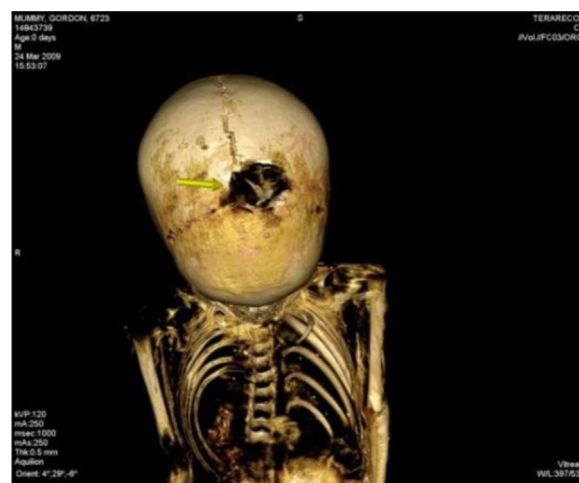


Fig. 1. Defect at the site of the anterior fontanelle in the skull of mummy 1.

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